PhD Proposition – ANR JCJC Project: *DUINTACOS*

Deep Understanding of INterface formation in fiber reinforced thermoplastic TApes for high quality COmposite Structures

Information

Affiliation: LMGC, IMT Mines Alès, Université de Montpellier, CNRS

Doctoral School: I2S - Information, Structure, Systèmes (University of Montpellier)

Specialization: Mechanical and Civil Engineering

Research teams: DMS and PCH (IMT Mines Alès)

Supervisors: M.F. Pucci, P-J. Liotier, P. Ienny

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Keywords

Thermoplastic polymers, tapes, (bio-based) composites, wetting, impregnation, crystallization, manufacturing.

Thesis topic

The thesis is part of a research project funded by ANR (**ANR JCJC DUINTACOS**). This project fits the context of **composite processing** for **sustainable industrial applications**. The future of composites consists in obtaining lighter parts, using more sustainable materials. Changing the nature of fibers and matrix (using bio-based and/or circular materials reinforced thermoplastics) requires a total control of composite manufacturing and above all of the quality of fiber/matrix interface. Therefore, it is fundamental to understand the mechanisms of interface formation and adhesion between fibers and matrix, the consolidation and the induced mechanical properties as well, at the microscopic and mesoscopic scales before to characterize the scale of composite.

Continuous fibers composite tapes are more and more used in the transportation industry since their use opens the possibility to process light composite structures with complex shapes, thanks to innovative processes (*i.e.* Automated Fiber Placement - AFP). Tapes

constituted by high performance materials, e.g. carbon fiber - reinforced poly (ether ether ketone) (PEEK) are used for aerospace applications [1] and, in parallel, a large variety of tapes are developed with different types of reinforcements, included bio-based ones [2]. Process steps at the scale of composite are studied (automated tape laying, composite molding, consolidation) with the aim of minimizing defects or porosity in composite parts and then, to obtain their highest mechanical properties [3]. Those defects reflect the quality of fiber/matrix interface that plays a primordial role on the mechanical behavior of composite parts [4]. On the other hand, the quality of fiber/matrix interface is less investigated at the mesoscopic scale of tape where micro-porosities can be observed. These porosities are characterized, but **mechanisms of micro-voids formation are still misunderstood**, even if they constitute a non-negligible part of total porosities of composites manufactured with those processes. Indeed, **the focus of the thesis** will be the **deep understanding of fiber/matrix interface formation and consolidation, considering high temperatures and the consequent cooling, at microscopic and mesoscopic scales**, to simulate the process conditions.

The first part of the thesis will focus on the **impregnation of molten thermoplastic in fiber tapes,** studying the effect of temperature on surface energies of polymers and fibers and the generated adhesion. Then, the dynamic wetting of polymer on fiber surface will also be characterized, in order to identify key parameters affecting impregnation. The second part of the thesis will focus on the **crystallization of thermoplastic matrix**, **the fiber induced nucleation and the generated crystalline morphology**. The last part will be focused on the characterization of **induced mechanical properties of interface** at different scales. A schematic drawing presenting the concept of the study is shown in Figure 1.

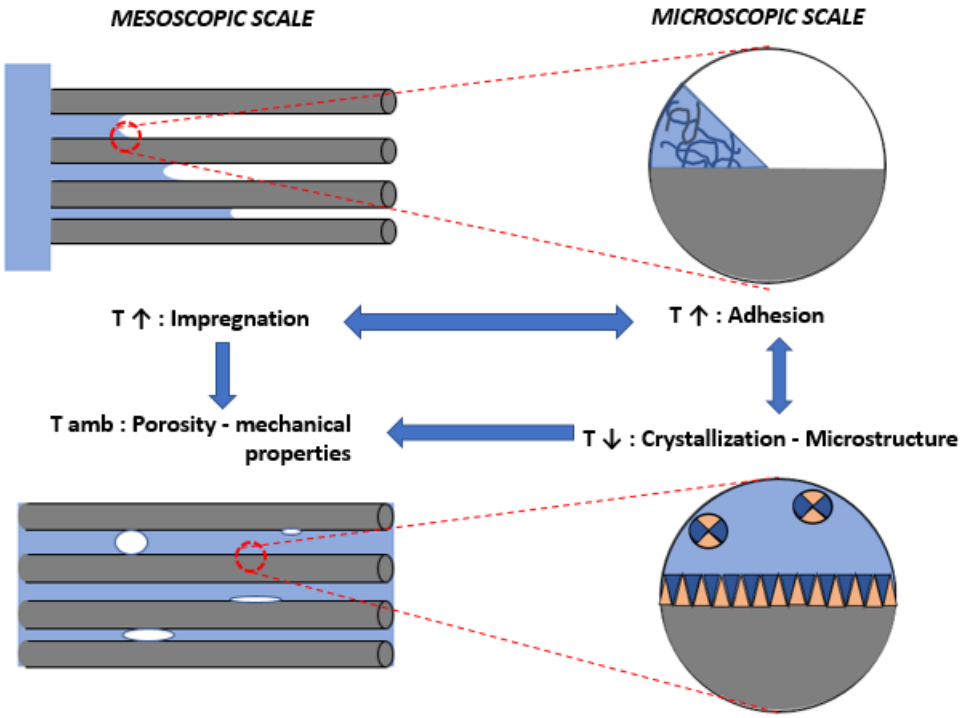

Figure 1 Schematic drawing of study concept.

This work needs the **development of reliable and original experimental methods** to physico-chemically characterize constituents and semi-products with the aim of revealing the relationship between the microstructure and the interface properties to obtain high quality composite structures. The PhD student will integrate a research team having an expertise on Liquid Composite Molding process and wetting phenomena, inducing porosity formation [4-10]. Methods set in this study will lead to the establishment of **demonstrators (like circular recycled tapes)** that will inspire new commercially suitable semi-products of high performances, but also with bio- and recycled petroleum-based materials. The deep understanding of fiber/thermoplastic matrix interfaces will allow to achieve maximal material health and then high quality composite structures, even for biodegradable and recycled ones.

Results obtained may have a strong impact on all industries of transport, due to the large panel of considered materials: high performance fibers and polymers (*e.g.* carbon/PEEK) for aeronautic applications, but also bio-based and biodegradable constituents (*e.g.* flax/PP, flax/PLA) for automobile industry. Expected results will have a significant interest for manufacturers in the field of AFP. The application domains are the decarbonisation of the aeronautic sector to be finally able to build flying structures light enough to be powered by renewable energies. It will also have a significant impact on the design of fully bio-based, biodegradable or recycled and recyclable composite structures. Those last applications are required to durably change the use of composite materials and make them really sustainable and circular.

Thesis supervision

Thesis will take place at the C2MA (IMT Mines Alès):

https://www.mines-ales.fr/ecole/imt-mines-ales/les-centres-de-recherche-et-denseignement/c2ma

The Material Research Center of Mines Alès (C2MA) is one of the three research centers at IMT Mines Alès. Its expertise concerns the development of materials for transport, building and packaging industry with a focus on bio-based and recycled materials to minimize their impact on the environment. It provides the strategic link between training, research and economic development activities in these areas. The candidate for the proposed thesis will work with members of two C2MA teams: the Hybrid Polymers and Composites (PCH) team, whose objective is the development of low-impact multifunctional polymer, composite and hybrid materials, and the Eco-Sustainability of Materials and Structures (DMS) team, which contributes to the development of eco-materials with improved mechanical performance and addressing durability criteria. The main objective of the research teams is to reveal the relationships between processing, microstructure and functional properties of materials.

National and international academic collaborations are also planned: IMT Mines Albi - Institut Clément Ader (ICA) and the Sapienza University of Rome (Italy). The PhD student will have the opportunity to make mobility in other partner laboratories and to participate to national and international conferences and workshops. The PhD student will also have the opportunity to publish thesis results in international scientific journals.

Required profile

- Master 2 / Engineering Degree in Mechanics of Materials and/or Material Sciences (obtained or upcoming);
- Skills in development and adaptation of experimental methods;
- Interest in experimental work, applied research and modeling;
- Competences and interest in polymers and composites, bio-based materials and material processing.
- Good level in English and scientific communication (written and oral)

Contacts

Candidates have to send a CV and an application letter describing their research experiences and of interest areas to:

Monica Francesca Pucci, Assistant Professor at IMT MINES Alès.
Equipe DMS, Centre de Matériaux des Mines d'Alès & LMGC UMR CNRS 5508 IMT Mines Alès
Tel : (+33) (0)4-66-78-56-30 ; Mail : monica.pucci@mines-ales.fr

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